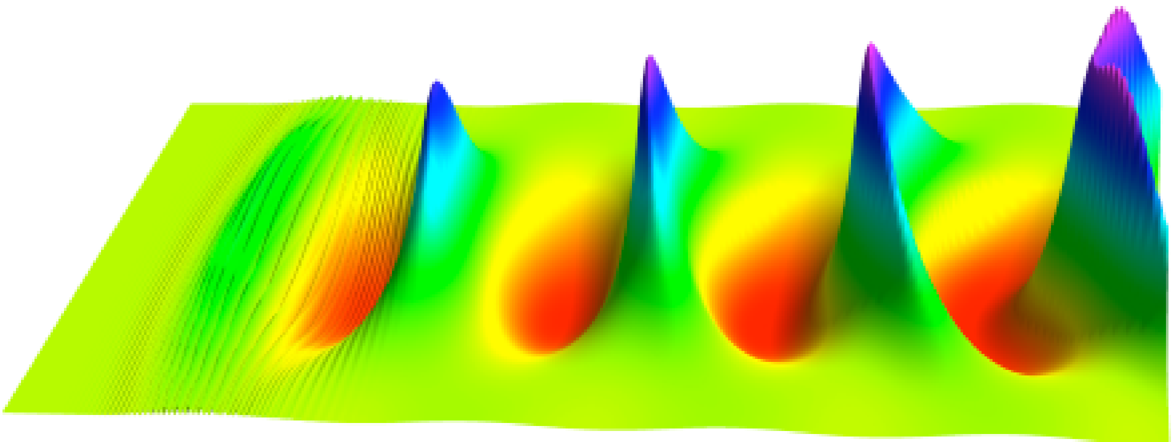
The Wave of the Future…



The Synergy of Accelerator Physics and High-Performance Computing

I'm thinking that the cover is done as a turn page, with the "wave" in the background. I'm open to ideas on how to incorporate something of our history, exemplified by the photo of Lawrence, into the cover, including "not at all." The Berkeley Lab logo should be prominent though secondary on the cover. I've tried to stay out of putting text on the cover. Something else to consider, if you don't think it would make the design too busy, is to put historical photos (184-Inch framework, magnets, etc.) as background screens (here and on interior pages).

BERKELEY LAB

Particle accelerators are critical to research in many fields—in fact, they are relevant to all four strategic elements in the science portfolio of the Department of Energy's Office of Science. Today's advanced accelerators are among the largest and most complex of all scientific instruments; many phenomena must be modeled (some of which were not encountered or even predicted until certain levels of energy or beam intensity were reached), and the design of the physical machine is in some cases very critical. Thus high-performance computing has rapidly gone from desirable to indispensable for enhancing existing facilities, designing the next generation, and exploring advanced concepts.

The long-term dream for the upcoming terascale era is an array of codes that together provide complete end-to-end modeling of all the phenomena that are important in an accelerator. This is truly the grand challenge of high-performance computing in support of accelerators. Meanwhile, every improvement in computer performance and in the simulation tools and underlying computational methods allows us to make the models more accurate and to attempt simulations previously considered intractable.

The development of next-generation accelerators and new accelerator technologies will require advances in Computational Accelerator Science (CAS). This includes the development of grid generation tools, mathematical algorithms, computational methods, and visualization tools, all of which must be implemented on and optimized for parallel computing environments.

CAS benefits the accelerator community in three main areas:

- Electromagnetic modeling of geometrically complex 3D accelerator structures and components.
- Simulation of beam dynamics in accelerators.
- Exploration of advanced concepts, often involving a combination of particle beams, lasers, and plasmas.

All the advanced accelerator projects of the future, including next-generation linear colliders, muon or neutrino factories, and hadron colliders, will require contributions from high-performance computing; the complexity of the machines, the performance parameters required by the users, and the financial stakes demand it.

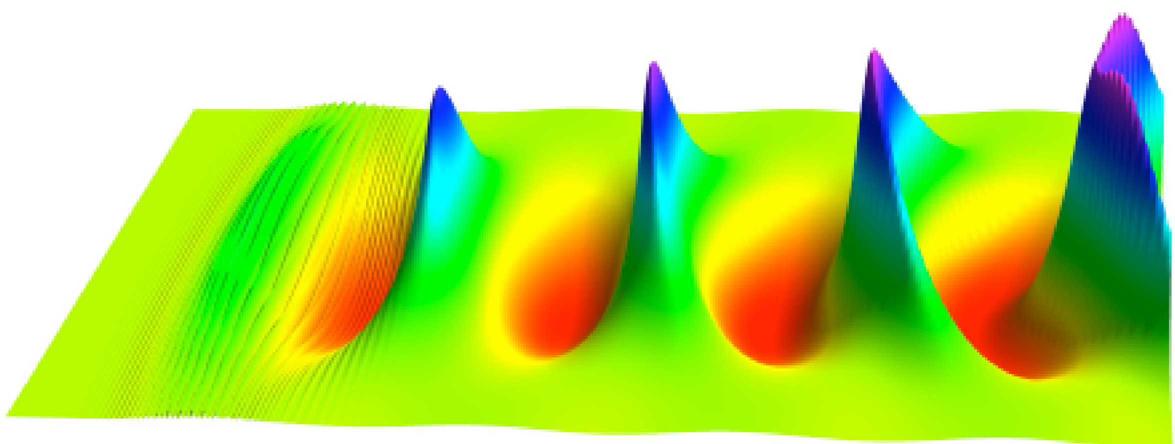
[Here I need to capture three likely-looking stages from Miguel's animated GIF of ECE]

Above: The "electron-cloud effect" is one of many phenomena that were only recently discovered, or hitherto could be neglected, that will take on great importance in future accelerators like a next-generation linear collider.

On the cover: Much has changed in the eight decades since Ernest Orlando Lawrence invented the cyclotron, but his namesake laboratory in Berkeley remains committed to leadership in key aspects of accelerator science in technology. One of these areas is theoretical, computational, and experimental research on advanced laser-driven plasma-based accelerators.

Simulation of Advanced Concepts

Since high energy accelerators cannot grow in size indefinitely, it will be necessary to develop new technologies capable of higher acceleration gradients than the ones now used. One possible approach is to use the extremely high fields that can be generated in lasers and plasmas. If these benchtop experiments could be developed into useable accelerators of much smaller size than the ones we use today, the payoff would be immense, not only in high energy physics but in applications of the beams. Thanks to the confluence of three things – successful small-scale experiments, the availability of terascale computing resources, and the availability of parallel 3D codes for modeling laser/plasma accelerators – it is now possible for full-scale simulations to play a pivotal role in guiding experiments. In addition, the fundamental physics inherent in ultra-intense laser and beam-plasma interactions is rich in nonlinear, ultra-fast, and relativistic physics. The insight gained from large-scale particle-in-cell codes is essential for unraveling this new physics.



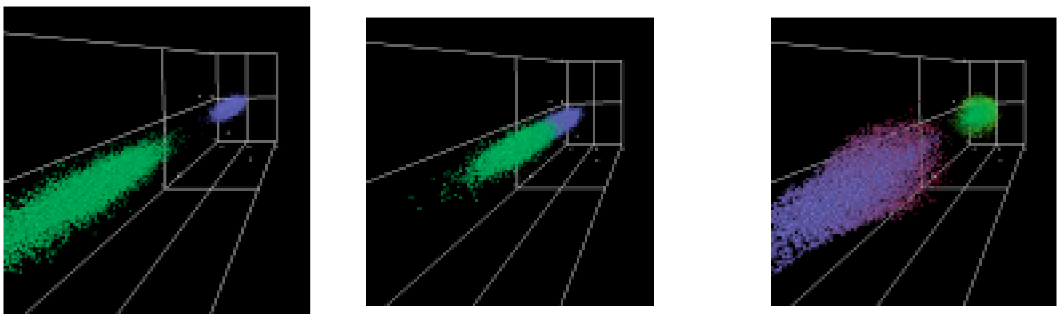
Caption: One of Berkeley Lab's centers of excellence is theoretical, computational, and experimental research on advanced laser-driven plasma-based accelerators. These devices are capable of sustaining ultrahigh accelerating gradients (10-100 GV/m, some three orders of magnitude beyond conventional technology) at their present laboratory scale, and are promising candidates as future compact high-energy accelerators and drivers for novel short-pulse radiation sources. The accelerating fields are due to an electron density wave generated by the radiation pressure of a high-intensity laser pulse moving through a plasma. The centerpiece of the l'OASIS Laboratory experimental program is a 10 TW (presently being upgraded to 100 TW), 50 fs, 10 Hz Ti:sapphire laser system. The highly nonlinear laser-plasma interaction is modeled numerically with relativistic fluid-Maxwell codes and with particle-in-cell codes. Here we see a simulation of the plasma density wave (propagating from left to right after being excited in the wake of a high-intensity laser pulse), obtained from a fluid code.

Credit line: Bradley Shadwick and Eric Esarey

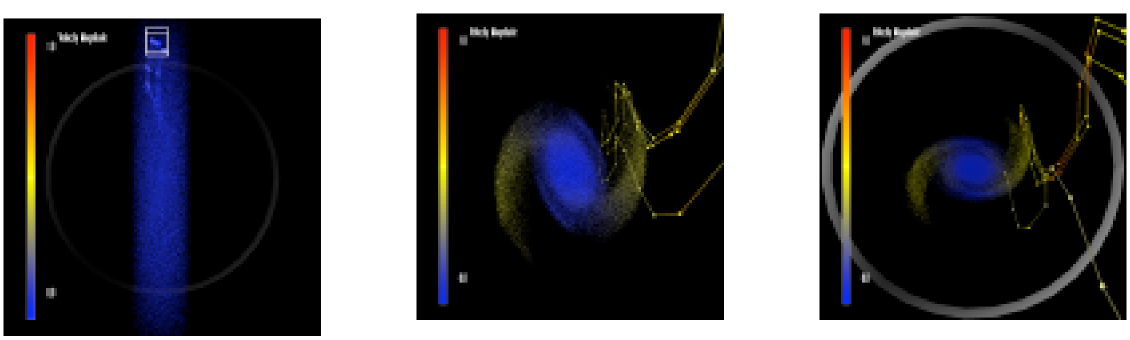
Simulation Studies of Beam Dynamics

As particle beams are accelerated and focused they undergo tremendously complicated interactions with their electromagnetic environment. This environment includes the physical structure of the accelerator, other beams (as in a collider or a parallel-beam fusion driver), and the manipulations that are performed in order to improve and control the beams.

The three-dimensional, nonlinear, multi-scale, many-body, and time-dependent characteristics of future accelerator design problems, and the complexity and immensity of the associated computations, add up to extreme technical difficulty. Solving these problems will require developing a terascale simulation capability by a multi-institutional, multi-disciplinary team operating at the confluence of accelerator science, applied mathematics, and information technology.

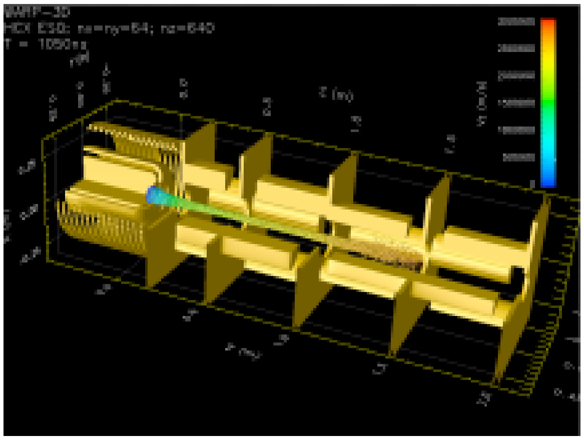


Caption: Maximizing the luminosity (and thus, ultimately, the users' productivity) at colliders requires an understanding of the electromagnetic interaction between the beams. This sequence comes from a three-dimesional simulation of an electron bunch colliding with a positron bunch. The ability to accurately model and predict performance represented by this simulation is important to many projects that seek to improve the performance of existing colliders and design new ones. *Cheryl, these pictures, especially the ones above, can be made larger as you see fit.*
Credit line: Christina Siegriest and [other names?]



Caption: In these frames from another simulation, the high density region is the beam core. Selected particles of interest, depending on the physical problem under study, are shown as streamlines. In this case, the streamlines correspond to halo particles in a very low density region far from the core. The spiral arms show the result of the beam being improperly injected into the accelerator, which in this case is a separated sector cyclotron.

Credit line: Andreas Adelmann (NERSC) and [other names?]



Caption: The applications of advanced accelerators extend far beyond their origins in high-energy and nuclear physics. This is a frame from a WARP3D simulation of an intense, high-current, space-charge-dominated heavy-ion beam's progress through the High-Current Experiment. The HCX is the present step in a program, performed jointly with Lawrence Livermore National Laboratory and Princeton Plasma Physics Laboratory, to develop heavy-ion accelerators as efficient and cost-effective "drivers" for inertial fusion energy. We believe this to be the first fully 3-D, time dependent simulation of an entire machine. *Cheryl, this picture may be cropped, etc. – the accelerator and beam are the interesting parts.*
Credit line: Alex Friedman and [other names?]

Electromagnetic Design of Accelerator Components

As particle beams are accelerated and focused they undergo tremendously complicated interactions with their electromagnetic environment. This environment includes the physical structure of the accelerator, any other beams that may be present (for example, the multiple bunches that pass and in some cases cross each other in a collider, or the numerous intense bunches accelerated in parallel in concepts for inertial-fusion drivers) and the manipulations that are performed in order to improve and control the beams.

Rob, I have some renderings of the PEP-II and notional NLC cavity; do you have any pointers toward someone who would have a particular "golden" one?

Caption: This finite-element model shows wall heating in an rf cavity for the PEP-II "B Factory" collider now in operation at the Stanford Linear Accelerator Center. The cavity is a complicated 3-D shape in which small details of design are hugely important. It was designed by Berkeley Lab to accelerate the beam efficiently while diverting undesirable higher-order modes into an external sink. Successfully tested in PEP-II, the concept is now being further explored for use in damping rings for a next-generation linear collider.

For more information on how advances in computer techniques are being put to use in the particle-accelerator field by Berkeley Lab and its collaborators, including links to technical papers and movies of many of these simulations, please visit our website at
http://www.whateverourURLis.lbl.gov

And in fine print at the bottom of the last page we have whatever administrative information needs to go on this kind of document per TEID.